

# Ensemble X-ray variability of active galactic nuclei from serendipitous source catalogues<sup>★</sup>

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## ABSTRACT

**Context.** The X-ray variability of the active galactic nuclei (AGN) has been most often investigated with studies of individual, nearby sources, and only a few ensemble analyses have been applied to large samples in wide ranges of luminosity and redshift.

**Aims.** We aim to determine the ensemble variability properties of two serendipitously selected AGN samples extracted from the catalogues of XMM-Newton and Swift, with redshift between  $\sim 0.2$  and  $\sim 4.5$ , and X-ray luminosities, in the 0.5–4.5 keV band, between  $\sim 10^{43}$  erg/s and  $\sim 10^{46}$  erg/s.

**Methods.** We used the structure function (SF), which operates in the time domain, and allows for an ensemble analysis even when only a few observations are available for individual sources and the power spectral density (PSD) cannot be derived. The SF is also more appropriate than fractional variability and excess variance, because these parameters are biased by the duration of the monitoring time interval in the rest-frame, and therefore by cosmological time dilation.

**Results.** We find statistically consistent results for the two samples, with the SF described by a power law of the time lag, approximately as  $SF \propto \tau^{0.1}$ . We do not find evidence of the break in the SF, at variance with the case of lower luminosity AGNs. We confirm a strong anti-correlation of the variability with X-ray luminosity, accompanied by a change of the slope of the SF. We find evidence in support of a weak, intrinsic, average increase of X-ray variability with redshift.

**Conclusions.** The change of amplitude and slope of the SF with X-ray luminosity provides new constraints on both single oscillator models and multiple subunit models of variability.

**Key words.** Surveys - Galaxies: active - Quasars: general - X-rays: galaxies

## 1. Introduction

Active galactic nuclei (AGN) typically show flux variability in all wavebands and on different timescales from minutes to years. This behaviour has been widely used to constrain the size and location of the emission regions and to obtain information on the emission mechanisms as well as the processes that cause the variability itself.

In addition to the study of individual light curves, ensemble properties of statistical AGN samples have been investigated in the optical/UV band through the use of the structure function (SF) (e.g. Trevese et al. 1994; Cristiani et al. 1996; Vanden Berk et al. 2004), and in the X-rays through the analysis of the fractional variability (Almaini et al. 2000; Manners et al. 2002).

Optical variability has been found to increase with decreasing luminosity (e.g. Cristiani et al. 1996), and with increasing redshift (Giallongo et al. 1991). The average increase with redshift of the amplitude of variability can be explained by the fact that high-redshift sources are observed at a higher rest-frame frequency, where they are more variable (di Clemente et al. 1996). The stronger variability at higher frequency, in turn, is caused by a hardening of the spectral energy distribution (SED) in the brighter phase, as shown by ensemble analyses of multi-band optical photometry of quasar (QSO) samples (Trevese et al.

2001; Trevese & Vagnetti 2002). More recently, Vanden Berk et al. (2004) applied an ensemble analysis to a large sample of  $\sim 25,000$  QSOs observed at two epochs only with the Sloan Digital Sky Survey (SDSS). The authors analysed variability as a function of intrinsic luminosity, redshift, rest-frame frequency and time lag between the observations, proposing a weak, intrinsic increase of variability with redshift, in addition to the amount previously explained by the stronger variability at higher rest-frame frequency (di Clemente et al. 1996), although additional analyses have not confirmed this increase (e.g. MacLeod et al. 2010).

In the X-ray domain, variability occurs on shorter time scales than in any other band, and is thought to come from a hot corona close to the central black hole (BH). Most investigations concern the light curves of individual nearby Seyfert 1 AGNs (e.g. Uttley et al. 2002; Uttley & McHardy 2005). It has been found that low-luminosity AGNs are generally more variable than higher luminosity ones (e.g. Barr & Mushotzky 1986; Lawrence & Papadakis 1993; Green et al. 1993; Nandra et al. 1997), and that the variability amplitude is higher on long time scales than on short time scales (e.g. Markowitz & Edelson 2004). In addition, it has been suggested that variability also increases with redshift (Paolillo et al. 2004).

Proposed variability models include a single coherent oscillator (e.g. Almaini et al. 2000), a superposition of individual flares or spots (e.g. Lehto 1989; Abramowicz et al. 1991; Czerny et al. 2004), variable absorption and/or reflection (e.g. Abrassart & Czerny 2000; Miniutti & Fabian 2004; Chevallier et al. 2006).

<sup>★</sup> Tables 1 and 2 are available in electronic form at <http://www.aanda.org>

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The relation between X-ray and optical/UV variability may be due to either i) Compton up-scattering in the hot corona of optical photons emitted by the disk (Haardt & Maraschi 1991), or to ii) a reprocessing of X-rays into thermal optical emission by means of irradiation and heating of the accretion disk (Collin-Souffrin 1991). In the first case, variations in the optical/UV flux would lead to X-ray variations, and vice versa in the latter case. Cross-correlation analyses of well-sampled X-ray and optical/UV light curves allow us to constrain models for the cause of the variability. The main results obtained so far indicate a cross-correlation between X-ray and UV/optical variations on the timescale of days, and in some cases delays between the two bands have been measured, with both X-rays lagging the UV (e.g. Marshall et al. 2008; Doroshenko et al. 2009), and vice versa (e.g. Shemmer et al. 2001; Arévalo et al. 2009).

Even more insight into the relation between X-ray and optical/UV variability is given by the analysis of the X-ray/UV ratio and its variability. Vagnetti et al. (2010) have shown that variability of  $\alpha_{ox}^1$  increases as a function of time-lag for a sample of serendipitously selected AGNs with simultaneous X-ray and UV measurements. This contributes part of the observed dispersion in the  $\alpha_{ox}$ - $L_{UV}$  anti-correlation, while another contribution is given by intrinsic differences among the average values of each AGN.

In the present paper, we present for the first time an ensemble structure function analysis of the variability of AGNs in the X-ray band. We adopt two sets of multi-epoch X-ray measurements extracted from the serendipitous source catalogues of XMM-Newton (Watson et al. 2009) and Swift (Puccetti et al. 2011).

The paper is organised as follows. Section 2 describes the data extracted from the archival catalogues. Section 3 describes the computation of the structure functions, and discusses their shapes, their dependence on black hole mass and bolometric luminosity, as well as on X-ray luminosity and redshift. In Sect. 4 we discuss and summarise the results.

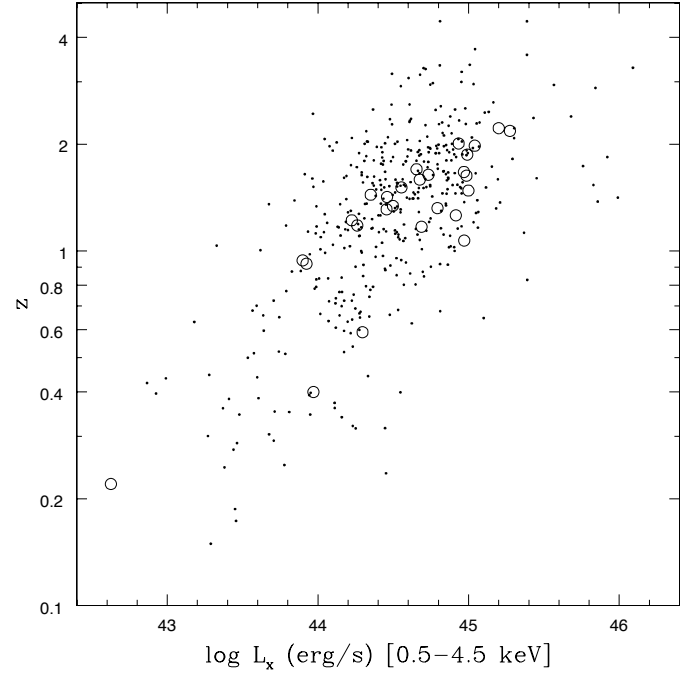
Throughout the paper, we adopt the cosmology  $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ,  $\Omega_m = 0.3$ , and  $\Omega_\Lambda = 0.7$ .

## 2. The data

### 2.1. XMM-Newton

The XMM-Newton Serendipitous Source Catalogue (XMMSSC) (Watson et al. 2009) is a comprehensive catalogue of serendipitous X-ray sources from the XMM-Newton observatory. The version presently available is 2XMMi-DR3, the latest incremental update of the second version of the catalogue<sup>2</sup>. It contains source detections drawn from 4953 XMM-Newton EPIC observations made between 2000 February 3 and 2008 October 08; all datasets were publicly available by 2009 October 31, but not all public observations are included in this catalogue. The total area of the catalogue fields is  $\sim 814 \text{ deg}^2$ , but taking account of the substantial overlaps between observations, the net sky area covered independently is  $\sim 504 \text{ deg}^2$ . The 2XMMi-DR3 catalogue contains 353191 detections (above the processing likelihood threshold of 6), related to 262902 unique X-ray sources, therefore a significant number of sources (41979) have more than one record within the catalogue.

We used the TOPCAT<sup>3</sup> software to extract the sources with repeated X-ray observations from the 2XMMi-DR3 catalogue



**Fig. 1.** Distribution of the sources in the  $L_X$ - $z$  plane. Dots: XMM-Newton sample; circles: Swift sample.

and cross-correlated this list with the DR7 edition of the SDSS Quasar Catalogue (Schneider et al. 2010) to obtain redshifts and spectral classifications of the sources. We used a maximum distance of 1.5 arcsec, corresponding to the uncertainty in the X-ray position, resulting in 412 quasars that were observed from 2 to 25 epochs each for a total of 1376 observations. We refer to these sources as the *XMM-Newton sample*, and report them in Table 1, where Col. 1 corresponds to the source serial number; Col. 2 gives the source name; Col. 3 the redshift; Col. 4 the number of observation epochs for the source; Col. 5 the average log of the X-ray flux in the observed 0.5-4.5 keV band, in  $\text{erg cm}^{-2} \text{ s}^{-1}$ ; Col. 6 the average log of the X-ray luminosity in the 0.5-4.5 keV band, in  $\text{erg s}^{-1}$ , computed with a photon index  $\Gamma = 1.8$ ; and Cols. 7 and 8 the log of the minimum and maximum lag between any two epochs of the light curve in the rest-frame of the source in days.

The sources are shown in the  $L_X$ - $z$  plane in Fig. 1 together with the sources of the Swift sample (Sect. 2.2). Here and throughout we adopted the same X-ray band 0.5-4.5 keV for the two samples. For XMMSSC, the flux was directly extracted from the EP9 band of the catalogue, while for the Swift sample the flux was computed from the Swift band 0.3-10 keV, adopting a photon index  $\Gamma = 1.8$ .

Typical monitoring times range from months to few years in the rest-frame. Some of the best sampled light curves with 10 or more epochs are shown in Fig. 2, with times in rest-frame days, counted from the initial epoch of each light curve.

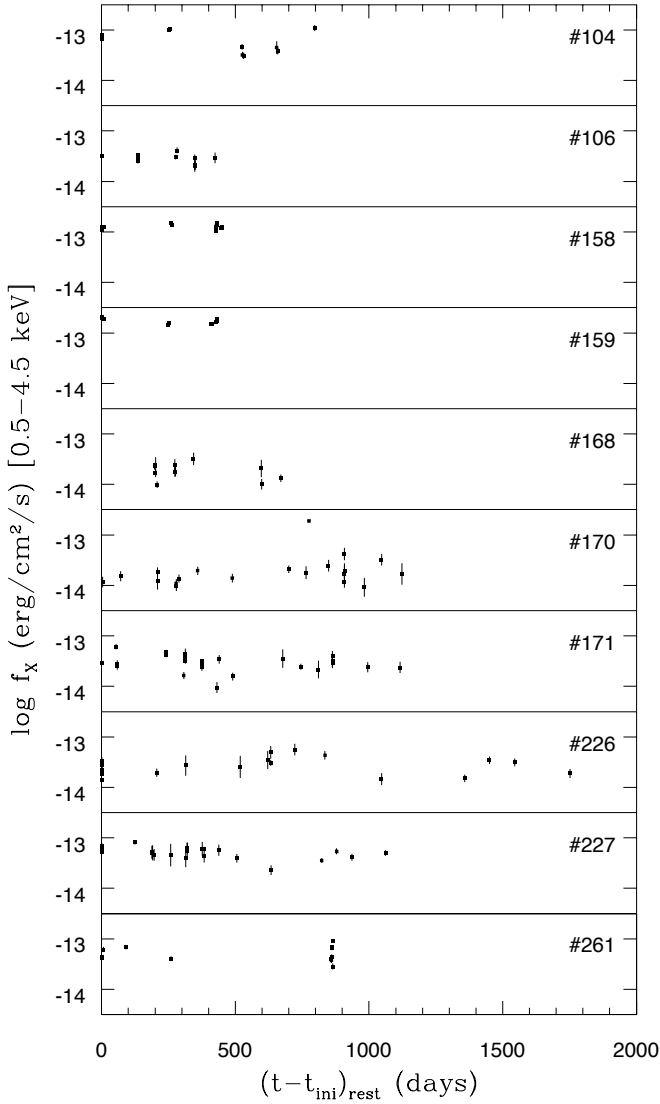
### 2.2. Swift

In the context of serendipitous surveys, the Swift satellite provides a unique capability. Although this space observatory is designed to discover gamma-ray bursts (GRB) (Gehrels et al. 2004), it is possible to use individual pointed observations of each GRB to build a large sample of deep X-ray images by stacking the individual exposures. To this purpose, Puccetti et al.

<sup>1</sup>  $\alpha_{ox} \equiv \log(L_{2 \text{ keV}}/L_{2500 \text{ \AA}})/\log(\nu_{2 \text{ keV}}/\nu_{2500 \text{ \AA}})$

<sup>2</sup> <http://xmmssc-www.star.le.ac.uk/Catalogue/>

<sup>3</sup> <http://www.star.bris.ac.uk/~mbt/topcat/>



**Fig. 2.** Some of the best-sampled light curves from the XMM-Newton sample. Times are counted from the initial epoch of each light curve in the rest-frame. Errors, proportional to the inverse square root of the photon count at each epoch, are displayed as  $3\text{-}\sigma$  values. Errors are discussed in more detail in Section 3. Source numbers from column 1 of Table 1 are indicated.

(2011) considered all Swift GRB observations from January 2005 to December 2008, with a total exposure time in the X-ray Telescope (XRT) longer than 10 ksec. These authors also analysed the XRT 0.5 Msec observation of the Chandra Deep Field South (CDFS) sky region. This set of observations is called the Swift Serendipitous Survey in deep XRT GRB Fields (S3XGF). These 374 images make up an unbiased X-ray survey because GRBs explode at random positions in the sky, and Puccetti et al. (2011) used them to define a well-suited statistical sample of X-ray point sources. The total exposure time of the survey is 36.8 Msec, with  $\sim 32\%$  of the fields with more than 100 ksec exposure time, and  $\sim 28\%$  with exposure time in the range 50-100 ksec. The survey covers a total area of  $\sim 32.55 \text{ deg}^2$ .

We used the preliminary version S3XGF catalogue, comprising GRB fields observed from January 2005 to June 2007, and cross-correlated it with the DR7 edition of the SDSS Quasar

Catalogue (Schneider et al. 2010) to obtain redshifts and spectral classifications.

We found 27 confirmed quasars with sufficient sampling (at least 100 photons in the light curve) to be used in the following SF analysis. These sources, to which we will refer as the *Swift sample*, are reported in Table 2, where Col. 1 corresponds to the source serial number; Col. 2 to the source name; Col. 3 gives the redshift; Col. 4 the number of time bins into which we divide the light curve according to the procedure described in the following; Col. 5 the average log of the X-ray flux in the band 0.5-4.5 keV, in  $\text{erg cm}^{-2} \text{ s}^{-1}$ ; Col. 6 the average log of the X-ray luminosity in the band 0.5-4.5 keV, in  $\text{erg s}^{-1}$ ; Col. 7 the GRB field where the source was observed.

The light curve files extracted from the Swift archive contain sequences of time intervals  $\Delta t_i$  between  $t_{\text{start},i}$  and  $t_{\text{stop},i}$ , in which the telescope was observing, with  $n_i$  the number of photons detected in each interval. We binned the light curves using a bin size  $\Delta t_{\text{bin}} = 5 \times 10^4 \text{ s}$ , which is a good compromise to obtain an average number of photons/bin  $\geq 10$  and a number of useful bins (i.e., bins with non-zero number of photons) in the light curve  $\geq 10$ . There is a negligible number of bins with zero photons, however. We assigned an average time  $t_j$  to each bin  $j$  weighted by the number of photons detected in the intervals (or fractions of intervals)  $\Delta t_i$  overlapped with the bin:  $t_j = \sum n_i t_i / \sum n_i$ , where  $t_i = (t_{\text{start},i} + t_{\text{stop},i})/2$ .

Some of the best-sampled light curves are shown in Fig. 3 with times in rest-frame days counted from the initial epoch of each light curve. Typical monitoring times range from some days to a few weeks in the rest-frame, and are therefore complementary to the time scales sampled by XMM-Newton.

The distribution of the Swift sample in the  $L_X$ - $z$  plane is shown in Fig. 1 together with the XMM-Newton sample.

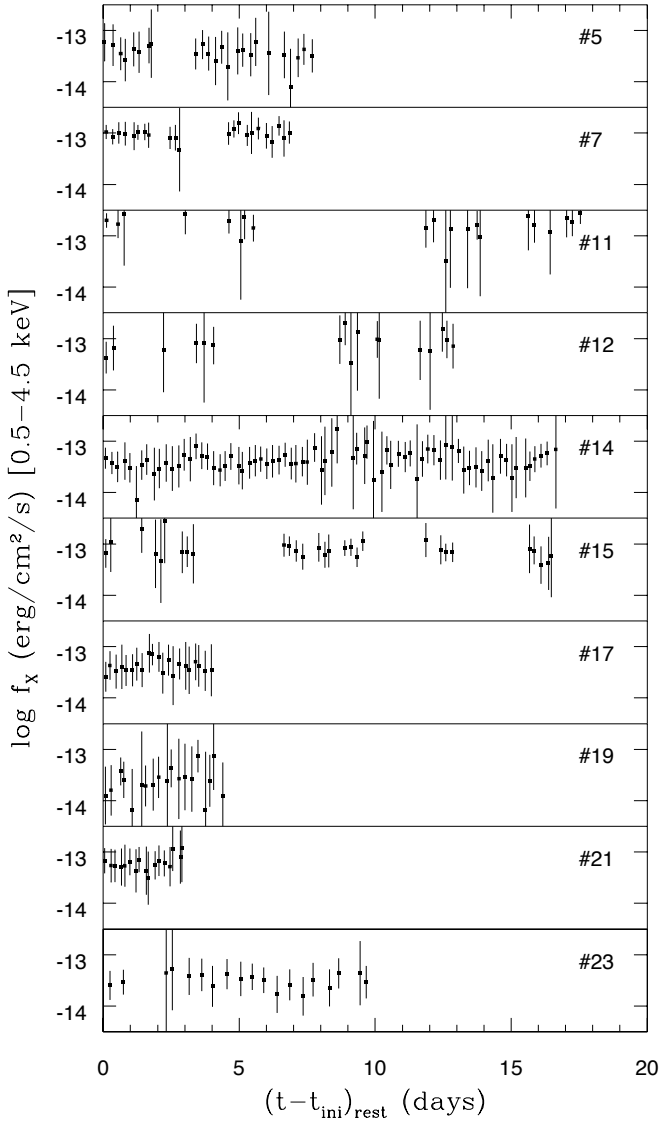
### 3. The structure function

The structure function (SF) has the great advantage of working in the time domain, which allows for an ensemble analysis even for extremely poor sampling of individual objects, when the harmonic content is completely lost. In this case, the structure function is to be preferred over power spectral density (PSD) analysis (e.g. Hughes et al. 1992; Collier & Peterson 2001; Favre et al. 2005). The SF was first introduced by Simonetti et al. (1985), and has since been used in various bands, including radio (e.g. Hughes et al. 1992), optical (e.g. Trevese et al. 1994; Kawaguchi et al. 1998; de Vries et al. 2003; Bauer et al. 2009), and X-ray (e.g. Fiore et al. 1998; Brinkmann et al. 2001; Gliozzi et al. 2001; Iyomoto & Makishima 2001; Zhang et al. 2002).

The SF provides a measure of the mean deviation for data points separated by a time lag  $\tau$ , and is defined in various ways in the literature. A variant in the definition concerns the use of the average square difference (e.g. Simonetti et al. 1985; Hughes et al. 1992) or the average of the absolute values of the differences (di Clemente et al. 1996). Another variant concerns the use of magnitudes or fluxes: while in the optical the SF is usually defined in terms of magnitude differences, in the X-rays and in the radio band the SF is most often defined in terms of flux differences, although there are exceptions, e.g. Fiore et al. (1998) introduced X-ray magnitudes and their differences.

For an analogy with the optical, we used the logarithm of the flux instead of the flux itself, and defined the SF with the following formula:

$$SF(\tau) \equiv \sqrt{\frac{\pi}{2} \langle |\log f_X(t + \tau) - \log f_X(t)|^2 - \sigma_n^2 \rangle} \quad (1)$$

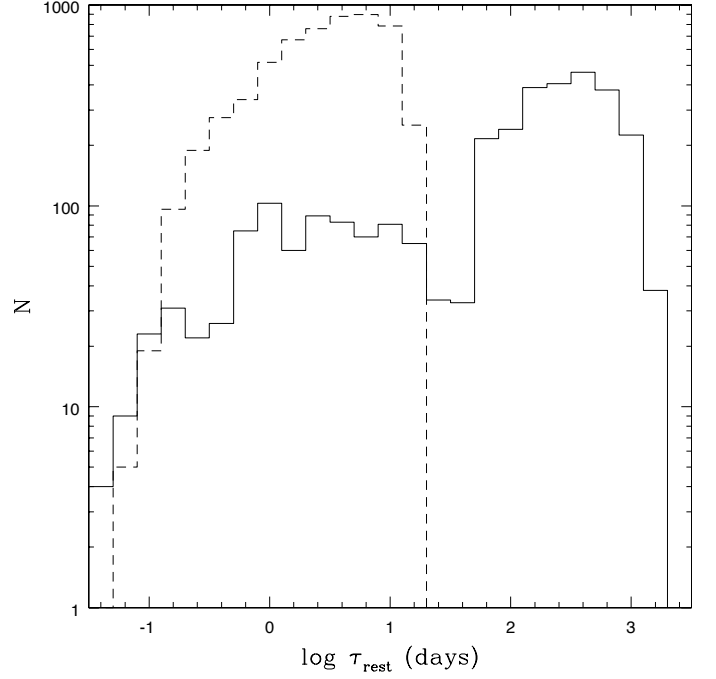


**Fig. 3.** Some of the best-sampled light curves from the Swift sample. Times are counted from the initial epoch of each light curve, in the rest-frame. Errors proportional to the inverse square root of the photon count at each epoch are displayed as  $3\text{-}\sigma$  values. Errors are discussed in more detail in Section 3. Source numbers from column 1 of Table 2 are indicated.

Here, the average of the absolute value of the difference is used, as in di Clemente et al. (1996);  $\sigma_n$  is the contribution of the photometric noise to the observed variations.  $f_X(t)$  and  $f_X(t + \tau)$  are two measures of the flux  $f_X$  in a given X-ray band at two epochs differing by the lag  $\tau$ . The factor  $\pi/2$  normalises SF to the rms value in the case of a Gaussian distribution. The X-ray band adopted in this paper is 0.5–4.5 keV, and the lag  $\tau$  is computed in the rest frame:

$$\tau_{\text{rest}} = \tau_{\text{obs}} / (1 + z) \quad . \quad (2)$$

While a definition in terms of flux differences could also be used for studies of individual sources, our definition with logarithmic differences, Eq. (1), is certainly preferable for an ensemble analysis, otherwise the contribution of faint sources would be negligible compared to that of brighter ones.



**Fig. 4.** Histogram of the rest-frame time lags contributing to the structure functions. Continuous histogram: XMM-Newton sample; dashed histogram: Swift sample.

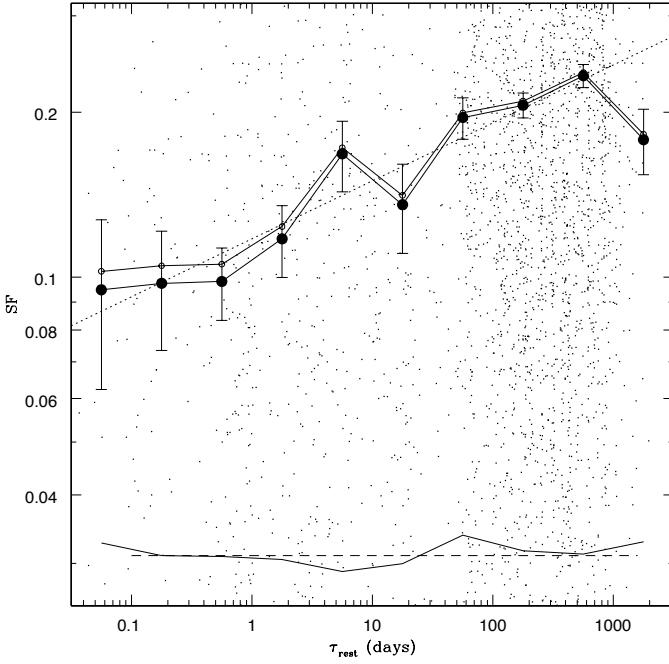
We now computed and compared the structure functions for the two samples. While the XMM-Newton sample is much larger than the Swift sample (412 sources vs 27 sources), the number of epochs is very small for most XMM-Newton sources (338/412=82% of the sources having less than 5 epochs), while the Swift light curves (with the adopted binning, see Sect 2.2) are better sampled, 21/27=78% of the sources having 10 or more bins (or “epochs”), with a mean number  $\sim 16$ . So the contributions of the two samples to the respective SFs are comparable in number, although different in the time scales sampled. The light-curve of the  $k$ -th source, with  $N_k$  epochs, contributes  $N_k(N_k - 1)/2$  points to  $SF(\tau_{\text{rest}})$ , for all the time lags  $\tau_{\text{rest},ij} = |t_i - t_j|/(1 + z)$ , where  $t_i$  and  $t_j$  are two epochs in the observer frame.

This can be seen in Figure 4, where the histograms of the rest-frame time lags are shown for the two samples, with bins of  $\Delta \log \tau = 0.2$ : hundreds of points contribute the most populated bins of each sample, which are days-weeks for the Swift sample and months-years for the XMM-Newton sample. The latter contributes also non-negligibly in the days-weeks range, with several tens of points.

In Figs. 5 and 6 we show the structure functions computed with Eq. (1) for the XMM-Newton and Swift samples, respectively.

To estimate the photometric noise  $\sigma_n$  in Eq. (1), we evaluated its contribution in each bin with the following considerations. The quadratic contribution of the noise to the SF is

$$\begin{aligned} \sigma_n^2 &= 2 \langle (\delta \log f_X)^2 \rangle \approx 2 (\log e)^2 \left\langle \left( \frac{\delta f_X}{f_X} \right)^2 \right\rangle = \\ &= 2 \cdot 0.434^2 \left\langle \frac{1}{N} \right\rangle = 0.377 \frac{\sum \frac{1}{N_k}}{N_p}, \end{aligned} \quad (3)$$

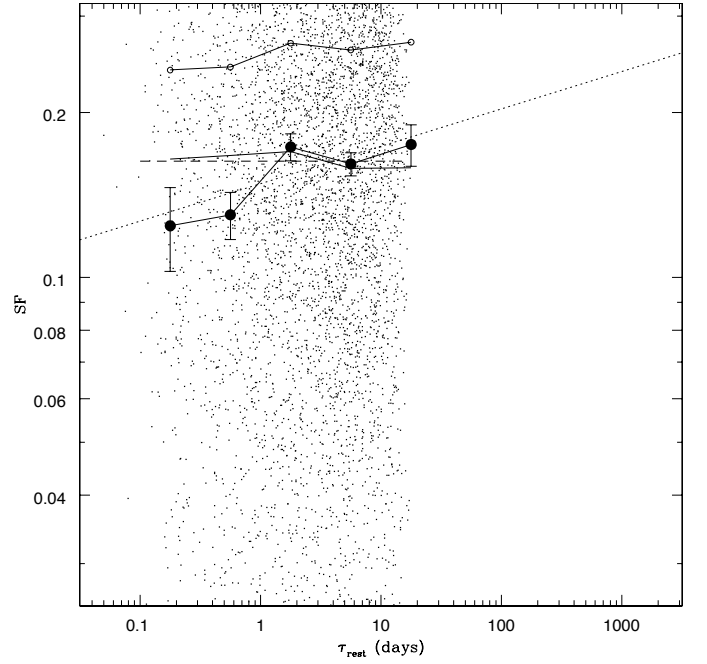


**Fig. 5.** Structure function for the XMM-Newton sample in bins of  $\Delta \log \tau = 0.5$ . The small empty circles and the continuous line connecting them show the uncorrected SF (i.e., neglecting  $\sigma_n$  in Eq. (1)). The larger filled circles and the line connecting them, show the SF corrected for the noise. The continuous line without data points indicates the average value of the noise in each bin, and the dashed, horizontal line is its weighted average, according to the number of points in each bin, adopted in Eq. (1). The dotted line is a weighted least-squares fit to the data of the bins. The small dots are the contributions from pairs of individual measurements at times differing by  $\tau$ .

where  $\delta f_X$  are the flux variations caused by noise alone (excluding source variability), and we assume  $\delta f_X / f_X = 1 / \sqrt{N}$ ,  $N$  being the number of counted photons at a given epoch, and its reciprocal is mediated in any given bin of the SF among the  $N_p$  points, which are contributed by the various light-curves;  $N_k$  is the average photon count per epoch of the  $k$ -th light-curve; the factor 2 is due to the contribution of 2 independent measurements to each flux variation. The values obtained in each bin are connected and shown in Figs. 5 and 6 as thin, continuous lines, while their average values, weighted with the numbers of points in each bin, are shown as dashed lines.

The average values  $\sigma_n = 0.031$  (XMM-Newton sample) and  $\sigma_n = 0.163$  (Swift sample) were then inserted in Eq. (1) to compute the SF, which is shown in Figs. 5 and 6, both with and without noise subtraction. The noise so estimated is almost negligible for the XMM-Newton sample, and quite high for the Swift sample. This is mainly because of the smaller effective area of Swift, and also because of the longer exposures of the XMM-Newton observations, which are typically several tens of ks per epoch, while for Swift the light-curves are binned in intervals of 50 ks, with effective exposures within a small fraction of the bin, around 10 ks.

Although the two SFs appear different before noise subtraction, their slopes and amplitudes agree quite well after correction. We stress that noise subtraction is not parametrical, but consistently derived by the photon counts. The fits shown in Figures 5 and 6 are least squares of the bin representative



**Fig. 6.** Structure function for the Swift sample, in bins of  $\Delta \log \tau = 0.5$ . The small empty circles and the continuous line connecting them show the uncorrected SF (i.e., neglecting  $\sigma_n$  in Eq. (1)). The larger, filled circles and the line connecting them show the SF corrected for the noise. The continuous line without data points indicates the average value of the noise in each bin, and the dashed, horizontal line is their weighted average, according to the number of points in each bin, adopted in Eq. (1). The dotted line is a weighted least-squares fit to the data of the bins. The small dots are the contributions from pairs of individual measurements at times differing by  $\tau$ .

points, weighted with the number of individual points in each bin,  $\log SF = a + b \log \tau_{rest}$ , or

$$SF \propto \tau_{rest}^b \quad (4)$$

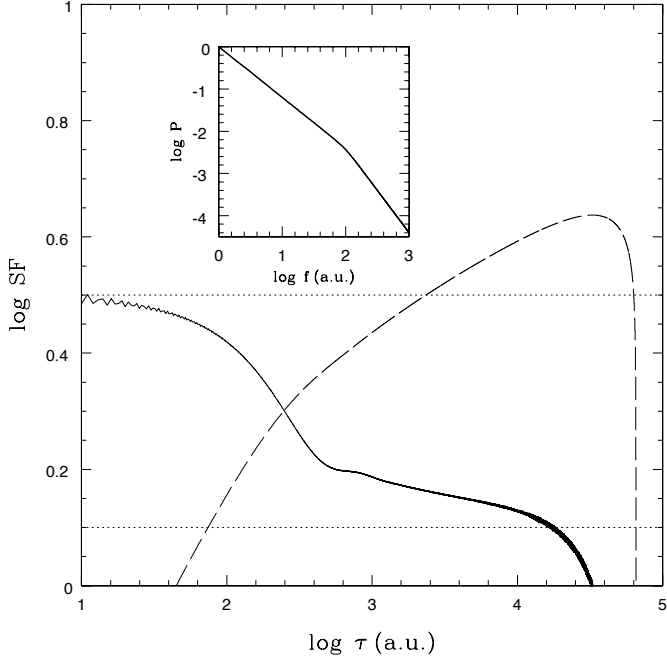
with consistent slopes,  $b = 0.10 \pm 0.01$  for the XMM-Newton sample, and  $b = 0.07 \pm 0.04$  for the Swift sample.

### 3.1. Relation with the PSD

X-ray variability of individual sources is usually analysed in terms of the PSD. This has been often described by a power-law,  $P(f) \propto f^{-\alpha}$ ,  $\alpha \sim 1.5$ , (e.g. Lawrence & Papadakis 1993). However, one or two breaks in the PSD of nearby AGNs have also been detected (e.g. Markowitz et al. 2003; O'Neill et al. 2005), and the PSD has been found to have a power-law exponent  $\alpha \approx 2$  for  $f > f_{HFB}$ ,  $\alpha \approx 1$  for  $f_{LFB} < f < f_{HFB}$ , and in some cases  $\alpha \approx 0$  for  $f < f_{LFB}$ . In turn, the high-frequency break has been found to be related to the mass of the central BH (e.g. Papadakis 2004).

An SF with the form of a single power-law as in Eq. (4) is equivalent to a single power-law PSD if the frequency range extends from 0 to  $\infty$ . Then a simple relation between the exponents holds (e.g. Kawaguchi et al. 1998; Bauer et al. 2009; Emmanoulopoulos et al. 2010):

$$\alpha = 1 + 2b. \quad (5)$$



**Fig. 7.** SF (dashed line) and its slope (continuous line) computed from a PSD shaped as a broken power-law, with  $\alpha_1 = 1.2$  and  $\alpha_2 = 2$ , shown in the inset. The dotted lines indicate the values of the power-law exponent  $b$ , expected from Eq. (5) for the single power-law case,  $b_1 = 0.1$ ,  $b_2 = 0.5$ . The cut-off in the SF at long  $\tau$  is caused by the finite number of Fourier frequencies used in the FFT calculation. Time lags and Fourier frequencies are in arbitrary units.

The slope of our SF,  $b \lesssim 0.1$ , would then correspond to a PSD exponent  $\alpha \lesssim 1.2$ , slightly flatter than the reference value  $\alpha \sim 1.5$  (Lawrence & Papadakis 1993).

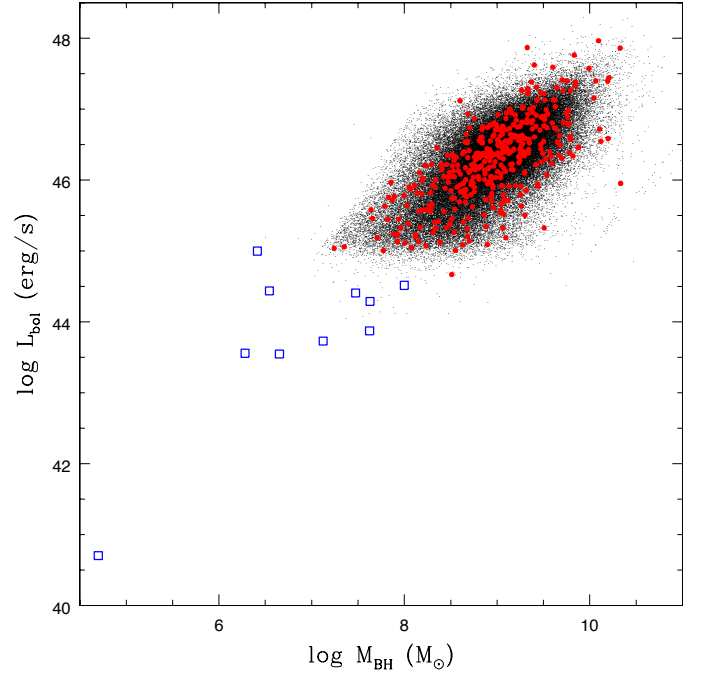
However, Eq. (5) does not straightforwardly apply when the PSD contains a break. Emmanoulopoulos et al. (2010) produced 2000 artificial light-curves with a PSD shaped as a broken power-law with a break at a given value  $f_B$ , and estimate the corresponding SFs. Figures 10 and 11 of Emmanoulopoulos et al. (2010) show that SFs also display a break whose distribution peaks around  $\tau_B \sim 1/f_B$ , but the SF slopes before and after this break do not agree with the relation of Eq. (5). In particular, the SF appears flatter than Eq. (5) below the break, and steeper above the break, resulting in less bending.

To analyse the relation between the shapes of PSD and SF, we evaluated the SF numerically via fast Fourier transform (FFT) techniques according to the relation  $SF(\tau) = 2 \int_0^\infty (1 - \cos(2\pi f\tau))P(f)df$  (e.g. Emmanoulopoulos et al. 2010), for a PSD shaped as a broken power-law. The result, shown in Fig. 7 for input PSD spectral indexes  $\alpha_1 = 1.2$ ,  $\alpha_2 = 2$ , is an SF shaped approximately as a broken power-law, but with a slope changing gradually and with less bending, which confirms the result by Emmanoulopoulos et al. (2010).

The above results suggest that we should expect some evidence of a break in the SF of AGNs with a typical broken power-law PSD.

### 3.2. Dependence on mass and bolometric luminosity

McHardy et al. (2006) proposed that the high-frequency break is related not only to the black hole mass,  $M_{BH}$ , but also to the



**Fig. 8.** Black hole masses and bolometric luminosities of AGN samples. Black dots:  $\sim 100,000$  sources from the Shen et al. (2011) catalogue. Red filled circles: XMM-Newton sample. Blue empty squares: low-luminosity AGNs from Uttley & McHardy (2005).

accretion rate in units of its Eddington value,  $\dot{m}_E \approx L_{bol}/L_{Edd}$ , and found the following relation

$$\log \tau_{break}(\text{days}) = 2.1 \log M_6 - 0.98 \log L_{44} - 2.32, \quad (6)$$

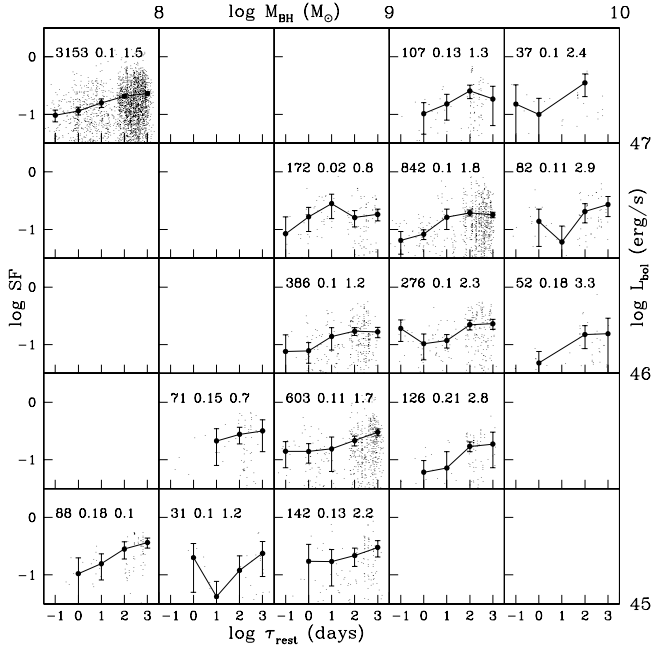
where we abbreviate  $M_6 = M_{BH}/10^6 M_\odot$  and  $L_{44} = L_{bol}/10^{44} \text{ erg/s}$ .

However, while for the light curves of individual objects the relation between SF and PSD is relatively simple, for an ensemble SF the different positions of the breaks should combine in the ensemble SF, possibly smoothing the result, depending on how the variability amplitude changes with  $M_{BH}$  and/or  $L_{bol}$ .

To find any break in the SF, we segregated our XMM-Newton sample according to  $M_{BH}$  and  $L_{bol}$  values. Estimates of the masses and bolometric luminosities were extracted from the catalogue of quasar properties by Shen et al. (2011). We show in Figure 8 the distribution of  $\sim 100,000$  AGNs from that catalogue in the plane  $M_{BH}$ - $L_{bol}$ , as well as the same distribution for our XMM-Newton sample, which appears quite similar, despite its smaller population (412 sources). We also show in the same figure some low-luminosity AGNs from Uttley & McHardy (2005), which will be discussed below.

We then plot in Figure 9 the structure function for XMM-Newton subsamples binned in intervals of  $\log M_{BH}$  and  $\log L_{bol}$ , with bin width  $\Delta \log M_{BH} = \Delta \log L_{bol} = 0.5$ . The SF is shown for subsamples with at least 30 SF points, in the range of masses  $10^{7.5} M_\odot < M_{BH} < 10^{10} M_\odot$  and luminosities  $10^{45} \text{ erg/s} < L_{bol} < 10^{47.5} \text{ erg/s}$ . The total number of SF points is reported in each box, as well as the average SF slope (weighted with the number of points in each bin of  $\tau_{rest}$ ), and the expected value of  $\log \tau_{break}$ , according to Eq. (6). The SF of the total XMM-Newton sample is also reported for comparison.

Our results do not support the existence of a break in the SF, expected following Eq. (6). However, we note that the analysis



**Fig. 9.** Structure function for XMM-Newton subsamples binned in intervals of  $\log M_{BH}$  and  $\log L_{bol}$ , with bin width  $\Delta \log M_{BH} = \Delta \log L_{bol} = 0.5$ . Values of  $M_{BH}$  and  $L_{bol}$  are reported in the upper and right axes, respectively. Subsamples with less than 30 SF points are not shown. The SF of the total XMM-Newton sample is reported, for comparison, in the first box in the upper left corner. The values reported in each box are the number of SF points, the average SF slope, and the expected value of  $\log \tau_{break}$ , according to Eq. (6). Contributions from pairs of individual measurements are also shown (dots).

by McHardy et al. (2006) is based on a few AGNs with quite low luminosities and masses (see Uttley & McHardy 2005), compared to our XMM-Newton sample, and the Shen et al. (2011) catalogue, see Figure 8.

The absence of a break in our results could be understood if Eq. (6), which appears to hold for AGNs with  $M_{BH} \lesssim 10^8 M_\odot$  and  $L_{bol} \lesssim 10^{45}$  erg/s, would not apply for larger masses and higher luminosities.

McHardy et al. (2006) associated the break time scale to a thermal or viscous time scale related to the inner radius of the accretion disk, and identify this with the transition radius  $R_{tr}$  predicted by Liu et al. (1999), based on evaporation of the inner disk in low Eddington ratio AGNs, describing the transition between an external cool thin disk and an inner, hot, advection-dominated accretion flow (ADAF). This model clearly does not apply to high-luminosity QSOs (see, e.g. Narayan et al. 1998).

### 3.3. Dependence on X-ray luminosity and redshift

Many authors have found inverse dependences of the X-ray variability on the X-ray luminosity  $L_X$ . Different variability indexes are used, so they must be briefly recalled to make comparisons.

Most authors use the *normalised excess variance* (e.g. Nandra et al. 1997; Vaughan et al. 2003), defined as  $\sigma_{NXS}^2 = (S^2 - \sigma_n^2)/\bar{x}^2$ , where  $S^2$  is the total variance of the light curve,  $\sigma_n^2$  is the mean square error, and  $\bar{x}$  is the mean of  $N$  total measurements; or the square root of it, which is also referred to as

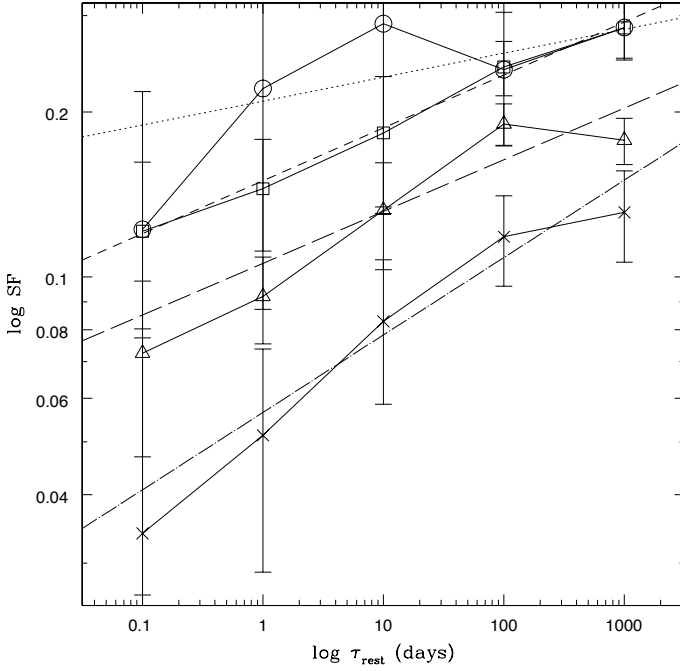
*fractional variability amplitude*,  $F_{var}$  (e.g. Markowitz & Edelson 2004).

Green et al. (1993) used the *normalised variability amplitude*, square root of the power at a specific frequency, normalised to the mean count rate of the related light curve. Lawrence & Papadakis (1993) used the amplitude of the power spectrum at a specific frequency.

As pointed out by Lawrence & Papadakis (1993),  $\sigma_{NXS}^2$  and  $F_{var}$  depend on the length of the monitored time interval. Moreover, we notice that they depend on redshift, because the time interval must be properly measured in the rest-frame of the source, as stressed by Giallongo et al. (1991) for the optical variability, and by Papadakis et al. (2008) for the X-ray case. So the comparison between different results must be taken with some caution. With these limitations in mind, and calling  $I_{var}$  a generic variability index (or its square root where appropriate), most of the previous results on the variability dependence on luminosity can be expressed in power-law form,  $I_{var} \propto L_X^{-k}$ . Values for the exponent  $k$  are usually about  $\sim 0.3$ , for time scales of days, and for samples including Seyfert galaxies and/or low- $z$  QSOs (Green et al. 1993; Lawrence & Papadakis 1993; Nandra et al. 1997; Markowitz & Edelson 2004). Similar values are found also for higher redshift QSOs, e.g. by Manners et al. (2002), up to  $z = 2$  ( $k = 0.27$ , still for time scales of days), and by Papadakis et al. (2008), up to  $z \sim 3.4$  ( $k = 0.33$ , for time scales of tens of days). Stronger dependences are instead found by Paolillo et al. (2004) ( $k \sim 0.65$ , in the redshift range  $0.5 < z < 1.3$ ) and by Almaini et al. (2000) ( $k = 0.75$ , for  $z < 0.5$ ). For longer time scales (years), a few analyses have been performed, e.g. Markowitz & Edelson (2004) found a weaker dependence,  $k \sim 0.13$ .

With the analysis of the rest-frame structure function, we can properly compare variability amplitudes at various time lags, and provide an unbiased characterisation of the dependence of variability on luminosity and redshift. In Figure 10 we show the SFs for four luminosity bins between  $L_X = 10^{43.5}$  erg/s and  $L_X = 10^{45.5}$  erg/s: a clear and strong dependence on  $L_X$  appears. A change in the slope of the SF is also present (between  $\sim 0.04$  and  $0.14$ ), implying that a different dependence on  $L_X$  is expected for different time lags. To see this, we re-plot in Figure 11 the SF data vs  $L_X$  for two different bins of time lag, centred on 1 day and 100 days, respectively. The least-squares fits, weighted with the number of measurements in each bin, correspond to power-law exponent  $k = 0.42 \pm 0.03$  for the shorter time scale, a slightly stronger dependence, compared to the results by most previous authors. For the longer time scale (100 days), our result is  $k = 0.21 \pm 0.07$ , which approximately agrees with the trend found by Markowitz & Edelson (2004).

A simple interpretation of the decrease of variability with luminosity ( $L$ ) is the superposition of  $N$  randomly flaring subunits. This was already considered in early studies of optical variability (e.g. Pica & Smith 1983; Aretxaga et al. 1997), and, in its simplest version of independent and identical flares, would predict a variability amplitude  $\propto N^{-1/2} \propto L^{-1/2}$ . In the X-ray domain, several authors have also considered the same argument (Green et al. 1993; Nandra et al. 1997; Almaini et al. 2000; Manners et al. 2002). The observed shallower slope can be understood invoking a correlation among flares (e.g. Green et al. 1993), or a dependence of the amplitude of the flares on the luminosity of the source (Almaini et al. 2000). We stress that a simple scaling of the flare amplitude with the luminosity of the source cannot account for the change in the slope of the SF with luminosity, shown in Figure 10, unless some correlation among the flares is also introduced.

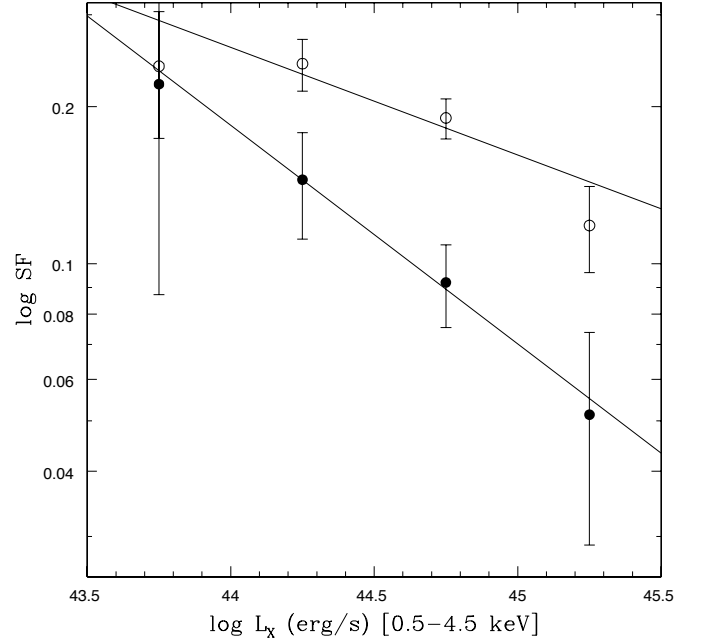


**Fig. 10.** Structure function in bins of X-ray luminosity, represented as points connected by continuous lines. Straight lines with different dash styles: least-squares fits weighted according to the number of points in each bin of time lag.  $10^{43.5} \text{ erg/s} < L_X < 10^{44} \text{ erg/s}$ : circles, dotted lines;  $10^{44} \text{ erg/s} < L_X < 10^{44.5} \text{ erg/s}$ : squares, short-dashed lines;  $10^{44.5} \text{ erg/s} < L_X < 10^{45} \text{ erg/s}$ : triangles, long-dashed lines;  $10^{45} \text{ erg/s} < L_X < 10^{45.5} \text{ erg/s}$ : crosses, dot-dashed lines.

Instead of multiple flaring subunits, models based on the variability of a single region have also been considered, e.g. Almaini et al. (2000) explained the dependence of variability on luminosity, invoking a relation between the luminosity and the size of the varying region, which produces a shift of the PSD in the frequency direction, with unchanged slope, under the assumption of self-similar scaling of the variable region. However, a PSD with slope independent on luminosity is inconsistent with our results on the SF (see Fig. 10), implying that a deviation from self-similarity should be considered.

The stronger dependences on  $L_X$  found by Almaini et al. (2000) and Paolillo et al. (2004) are accompanied by the suggestion of a possible increase of the variability with redshift. Almaini et al. (2000) find an opposite dependence on luminosity ( $k = -0.3$ ) for sources at  $z > 0.5$ , which could be caused by an increase with  $z$ . Paolillo et al. (2004) measure a higher variability for sources at  $z > 1.3$  than for their low- $z$  counterparts of similar luminosity. Manners et al. (2002) also reported tentative evidence of a stronger variability for sources at  $z > 2$ . Finally, Papadakis et al. (2008) compared the variability of high-redshift AGNs in the Lockman Hole region with that of nearby AGNs by Markowitz & Edelson (2004), finding evidence of an increase with redshift.

Owing to the strong correlation of sources in the  $L_X$ - $z$  plane (Fig. 1), we limited our analysis of the  $z$ -dependence to the sources in the luminosity interval  $10^{44} \text{ erg/s} < L_X < 10^{45} \text{ erg/s}$ , and divided the sample into four equally populated redshift bins,  $0 < z \leq 1$ ,  $1 < z \leq 1.4$ ,  $1.4 < z \leq 1.8$ ,  $1.8 < z \leq 4.5$ . The result, displayed in Figure 12, suggests the presence of a weak trend with redshift at intermediate time scales, while at short and



**Fig. 11.** Dependence of the SF on  $L_X$ . Filled circles:  $\tau_{rest} = 1$  d; open circles:  $\tau_{rest} = 100$  d. Lines: weighted least-squares fits, according to the number of points in each bin of  $L_X$ .

long timescales the behaviour appears unclear and possibly non-monotonic.

To investigate this dependence in more detail, we computed partial correlation coefficients of variability with redshift, considering all individual variations that contribute to the SF. While the ordinary correlation coefficient indicates no correlation,  $r_{Vz} = -0.06$ , with probability  $P(> r) = 0.001$ , the first-order partial correlation coefficient, which takes account of the dependence on  $L_X$ , is

$$r_{Vz,L} = (r_{Vz} - r_{VL}r_{zL}) / \sqrt{(1 - r_{VL}^2)(1 - r_{zL}^2)} = 0.125, \quad (7)$$

with probability  $P(> r) = 10^{-12}$ , suggesting the presence of a weak, intrinsic correlation. We also calculated the second-order partial correlation coefficient (Kendall & Stuart 1977), which compensates for both the dependences on  $L_X$  and on the time lag  $\tau$ , and still strengthens the correlation:

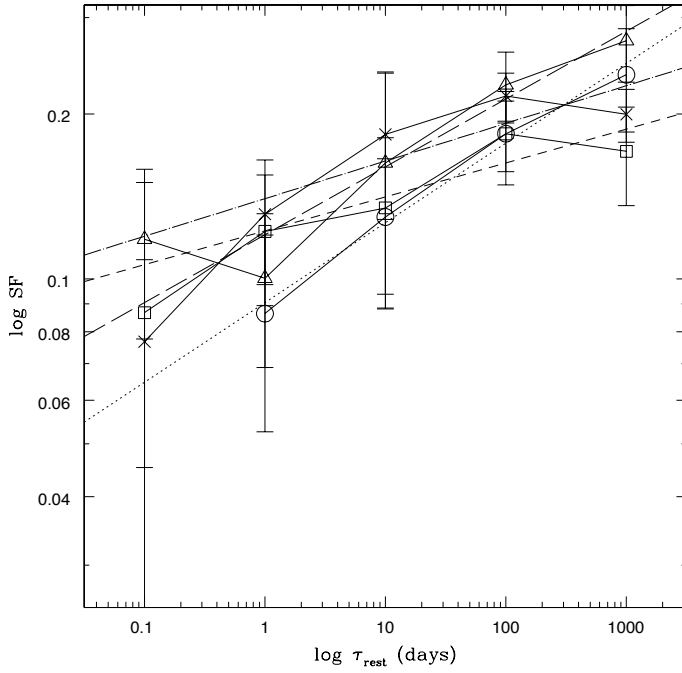
$$r_{Vz,L\tau} = (r_{Vz,L} - r_{V\tau,L}r_{z\tau,L}) / \sqrt{(1 - r_{V\tau,L}^2)(1 - r_{z\tau,L}^2)} = 0.127. \quad (8)$$

The probability is in this case  $P(> r) = 6 \cdot 10^{-13}$ .

#### 4. Discussion

The analysis of X-ray variability of AGNs has previously been performed mainly for individual nearby Seyferts or for small samples of them, and only a few works extend the study to large samples in wide ranges of luminosity and redshift (e.g. Almaini et al. 2000; Manners et al. 2002; Paolillo et al. 2004). Our study presents the first ensemble analysis based on the structure function. This is to be preferred for statistic studies compared with a PSD analysis, because SF operates in the time domain, is less dependent on irregular sampling, and allows for an analysis even with very few epochs. The SF is also preferable compared with the analysis of fractional variability and excess variance, because





**Fig. 12.** Structure function in bins of redshift for sources in the luminosity interval  $10^{44} \text{ erg/s} < L_X < 10^{45} \text{ erg/s}$ , represented as points connected by continuous lines. Straight lines with different dash styles: least-squares fits, weighted according to the number of points in each bin of time lag.  $0 < z \leq 1$ : circles, dotted lines;  $1 < z \leq 1.4$ : squares, short-dashed lines;  $1.4 < z \leq 1.8$ : triangles, long-dashed lines;  $1.8 < z \leq 4.5$ : crosses, dot-dashed lines.

these parameters are biased by the duration of the monitoring time interval in the rest-frame, and thus on cosmological time dilation.

Our variability analysis, based on two different serendipitously selected samples extracted from the catalogues of XMM-Newton (Watson et al. 2009) and Swift (Puccetti et al. 2011), gives statistically consistent results in the two cases, with the SF described by a power law of the time lag, with exponent  $b = 0.10 \pm 0.01$  (XMM-Newton) or  $b = 0.07 \pm 0.04$  (Swift). This would correspond to a PSD with power law exponent  $\alpha \approx 1.2$  for the case of a single-power-law PSD, which is within the range of exponents found for nearby Seyferts (Lawrence & Papadakis 1993).

While the PSD of local low-luminosity AGNs often shows one or two breaks, we do not find evidence of breaks in the SF, even dividing the analysis in bins of  $M_{BH}$  and  $L_{bol}$ . However, while a break at a time lag roughly proportional to the black hole mass is expected for local AGNs, our results do not support this expectation for more luminous AGNs and QSOs. This suggests that the relation found by McHardy et al. (2006), reported in Eq. (6), cannot be extrapolated to high bolometric luminosities and large black hole masses, possibly because the transition between an external cool thin disk and an inner ADAF (Liu et al. 1999) does not apply in the high-Eddington ratio regime.

We confirm a strong anti-correlation of the variability with X-ray luminosity, as  $L_X^{-0.42}$  and as  $L_X^{-0.21}$  for time lags  $\sim 1$  day and  $\sim 100$  days, respectively. This approximately agrees with most previous authors (Green et al. 1993; Lawrence & Papadakis 1993; Nandra et al. 1997; Markowitz & Edelson 2004; Papadakis et al. 2008).

The behaviour of the slope and amplitude of the SF as a function of the luminosity implies that (i) for a model of multiple flaring subunits, they cannot be uncorrelated, (ii) for a model with a single varying region self-similar scaling with luminosity cannot hold.

We find evidence in support of a weak, intrinsic, increase of the average X-ray variability with redshift. The dependence, however, appears tangled with that on the time lag. This suggests that different processes could dominate the variability at short and long time scales, and that their relative importance changes with the redshift.

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**Table 1.** XMM-Newton sample.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
1	2XMMi J001716.8-010725	1.163	2	-12.72	45.06	1.10	1.10
2	2XMMi J001808.7-005709	1.335	2	-13.39	44.53	1.06	1.06
3	2XMM J020011.5-093125	0.3604	2	-12.49	44.11	2.15	2.15
4	2XMM J020118.6-091936	0.6607	2	-12.73	44.48	2.06	2.06
5	2XMM J024040.8-081309	1.85	2	-13.92	44.32	2.75	2.75
6	2XMM J024055.8-081952	1.801	2	-13.84	44.37	2.76	2.76
7	2XMM J024105.8-081153	0.9785	2	-13.66	43.95	2.91	2.91
8	2XMM J024125.9-080936	3.072	2	-14.13	44.60	2.60	2.60
9	2XMM J024149.9-000433	1.26	2	-13.46	44.40	-0.43	-0.43
10	2XMM J024157.1+000703	1.563	2	-13.46	44.62	-0.48	-0.48
11	2XMM J024200.8+000021	1.104	2	-12.85	44.88	-0.39	-0.39
12	2XMM J024204.7+000814	0.3822	2	-13.25	43.41	-0.21	-0.21
13	2XMM J024207.2+000038	0.3842	2	-13.06	43.61	-0.21	-0.21
14	2XMM J024215.0-000209	1.01	2	-13.62	44.02	-0.37	-0.37
15	2XMM J024227.3+000846	0.6501	2	-13.45	43.74	-0.29	-0.29
16	2XMM J024250.8-000030	2.177	2	-14.08	44.32	-0.57	-0.57
17	2XMM J024251.0+001010	1.888	2	-13.27	45.00	-0.53	-0.53
18	2XMM J024304.6+000005	1.995	2	-13.51	44.80	-0.55	-0.55
19	2XMM J024308.1-000126	0.6787	2	-13.67	43.57	-0.30	-0.30
20	2XMM J030707.3-000424	0.6641	2	-13.20	44.02	2.50	2.50
21	2XMM J032108.4+413221	2.467	2	-13.39	45.13	2.32	2.32
22	2XMM J033627.4+004653	1.746	3	-13.96	44.22	2.15	2.53
23	2XMM J033639.5+002535	1.68	9	-13.31	44.84	-0.22	2.79
24	2XMM J033654.2+004015	2.625	6	-13.42	45.16	-0.35	2.66
25	2XMM J033701.1+004312	2.006	3	-14.01	44.31	2.11	2.49
26	2XMM J033709.1+004614	2.506	4	-14.17	44.37	-0.34	2.42
27	2XMM J033711.5+004344	1.918	3	-14.18	44.10	1.79	2.40
28	2XMM J033715.6+004206	2.354	6	-14.00	44.48	-0.32	2.44
29	2XMM J033716.5+003124	2.437	3	-14.54	43.97	1.71	2.03
30	2XMM J033718.8+003303	0.4371	7	-13.80	42.99	0.05	2.81
31	2XMM J033746.7+003510	1.4	2	-13.78	44.19	0.81	0.81
32	2XMM J033754.1+002934	2.004	2	-13.43	44.89	2.39	2.39
33	2XMM J033801.9+002719	1.583	2	-13.68	44.41	2.45	2.45
34	2XMM J073405.2+320315	2.082	2	-14.13	44.23	1.71	1.71
35	2XMMi J073654.0+302657	0.7238	2	-13.13	44.17	1.99	1.99
36	2XMMi J073708.1+303914	1.403	2	-13.36	44.61	1.85	1.85
37	2XMMi J073712.4+303637	0.9177	2	-12.73	44.81	1.95	1.95
38	2XMM J074222.3+494147	0.9274	6	-12.97	44.58	1.22	3.16
39	2XMM J080633.2+153810	0.9994	2	-13.34	44.29	2.57	2.57
40	2XMM J083102.9+523534	4.444	3	-14.26	44.81	0.47	2.57
41	2XMM J083740.2+245423	1.125	2	-12.38	45.37	1.93	1.93
42	2XMMi J083906.7+575417	1.534	2	-12.23	45.83	1.94	1.94
43	2XMMi J083924.8+575231	0.187	2	-12.52	43.45	2.27	2.27
44	2XMM J084659.3+344825	1.582	2	-13.23	44.86	2.12	2.12
45	2XMM J084710.0+345442	2.303	2	-13.63	44.82	2.01	2.01
46	2XMM J084905.0+445714	1.259	3	-13.44	44.41	-0.56	0.46
47	2XMM J084943.6+450023	1.593	3	-13.53	44.56	-0.62	0.40
48	2XMM J085346.1+200957	1.093	2	-13.18	44.53	2.26	2.26
49	2XMMi J090429.5+340544	1.297	2	-13.67	44.22	2.19	2.19
50	2XMMi J090505.5+341352	1.024	2	-12.78	44.87	2.25	2.25
51	2XMMi J090516.6+340921	1.872	2	-13.35	44.90	2.09	2.09
52	2XMMi J090525.2+341500	1.588	2	-13.58	44.51	2.14	2.14
53	2XMM J091301.0+525929	1.377	2	-12.09	45.86	1.11	1.11
54	2XMM J091302.8+530322	0.6307	2	-13.98	43.18	1.28	1.28
55	2XMM J091440.3+530038	1.43	2	-13.60	44.38	1.11	1.11
56	2XMM J091843.6+211819	0.8309	2	-13.45	43.99	2.71	2.71
57	2XMM J091848.6+211717	0.1493	2	-12.47	43.29	2.91	2.91
58	2XMM J091852.9+211518	1.035	2	-14.33	43.33	2.66	2.66
59	2XMM J091907.5+212553	1.39	2	-12.90	45.06	2.59	2.59

**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
60	2XMM J091908.7+212153	1.514	2	-13.32	44.72	2.57	2.57
61	2XMM J091914.2+303018	1.388	2	-14.11	43.84	2.78	2.78
62	2XMM J092039.7+301701	1.18	2	-14.00	43.79	-0.98	-0.98
63	2XMM J092104.3+302031	3.35	3	-13.80	45.01	-1.28	2.52
64	2XMM J093359.2+551550	1.863	2	-13.26	44.99	0.33	0.33
65	2XMM J093551.5+551117	1.79	2	-13.63	44.58	0.34	0.34
66	2XMM J093555.4+551238	1.8	2	-13.33	44.89	0.34	0.34
67	2XMM J094404.3+480647	0.3919	2	-12.74	43.94	1.32	1.32
68	2XMM J095251.5+013848	0.4997	2	-13.39	43.53	2.05	2.05
69	2XMM J095344.9+014251	1.657	2	-13.22	44.91	1.80	1.80
70	2XMM J095636.3+690028	1.975	3	-13.47	44.84	0.30	2.48
71	2XMM J095658.6+693852	2.035	2	-13.38	44.96	2.55	2.55
72	2XMM J095701.3+685500	1.297	3	-13.07	44.82	0.42	2.59
73	2XMMi J095750.0+013352	2.011	2	-13.88	44.45	1.00	1.00
74	2XMM J095754.7+023831	1.6	2	-14.14	43.96	1.14	1.14
75	2XMMi J095759.4+020435	2.034	3	-13.81	44.53	0.96	2.09
76	2XMM J095810.9+014004	2.101	3	-13.64	44.73	0.99	2.10
77	2XMM J095815.5+014922	1.509	6	-12.92	45.12	-1.01	2.20
78	2XMM J095819.8+022903	0.3454	3	-13.08	43.48	1.43	2.62
79	2XMMi J095820.5+020303	1.355	3	-14.26	43.67	1.11	2.20
80	2XMM J095822.2+014524	1.96	5	-13.57	44.73	-1.08	2.13
81	2XMM J095834.0+024427	1.887	2	-13.46	44.80	2.09	2.09
82	2XMMi J095834.7+014502	1.889	5	-13.99	44.27	-1.07	2.10
83	2XMM J095844.9+014309	1.337	5	-13.93	43.99	0.38	2.49
84	2XMM J095847.7+690533	1.288	3	-12.82	45.06	0.42	2.59
85	2XMM J095848.8+023441	1.549	6	-13.54	44.53	-0.18	2.34
86	2XMM J095852.1+025156	1.407	2	-13.31	44.66	2.17	2.17
87	2XMM J095857.3+021314	1.024	5	-12.75	44.90	0.44	2.79
88	2XMM J095858.6+020139	2.456	10	-13.41	45.11	-0.95	2.56
89	2XMM J095902.7+021906	0.3454	9	-12.61	43.95	-0.72	2.97
90	2XMM J095908.3+024309	1.318	2	-12.72	45.18	2.18	2.18
91	2XMM J095918.7+020951	1.156	7	-12.85	44.93	-0.09	2.76
92	2XMM J095924.4+015954	1.235	8	-13.09	44.75	-0.10	2.61
93	2XMM J095935.6+024838	1.973	2	-14.23	44.08	2.08	2.08
94	2XMM J095946.0+024743	1.066	3	-13.12	44.57	1.90	2.41
95	2XMM J095949.4+020141	1.753	8	-13.62	44.57	-0.84	2.59
96	2XMM J095958.0+014327	1.627	5	-13.93	44.19	-0.02	2.53
97	2XMM J100001.3+024845	0.7661	3	-13.20	44.16	1.97	2.47
98	2XMM J100008.0+013307	1.172	4	-13.80	43.99	1.91	2.62
99	2XMM J100012.9+023522	0.6984	6	-13.11	44.16	0.51	2.72
100	2XMM J100014.1+020054	2.498	7	-13.75	44.78	-0.95	2.49
101	2XMM J100024.3+015053	1.664	5	-13.85	44.29	0.35	2.61
102	2XMM J100024.6+023148	1.321	5	-13.40	44.51	0.38	2.58
103	2XMM J100025.2+015852	0.3726	7	-12.53	44.11	-0.54	2.90
104	2XMM J100043.1+020637	0.36	10	-13.23	43.37	-0.54	2.90
105	2XMM J100055.4+023442	1.404	8	-13.53	44.43	-0.97	2.58
106	2XMM J100058.8+015359	1.557	10	-13.55	44.53	-1.11	2.63
107	2XMM J100104.2+553522	1.535	2	-13.31	44.74	2.56	2.56
108	2XMM J100114.3+022356	1.796	6	-13.56	44.65	-1.04	2.41
109	2XMM J100116.7+014053	2.054	4	-13.75	44.59	-0.12	2.25
110	2XMM J100120.2+023341	1.834	5	-13.81	44.43	-1.04	2.51
111	2XMM J100120.7+555351	1.413	2	-11.98	45.99	2.58	2.58
112	2XMM J100130.3+014304	1.57	4	-14.04	44.04	-0.83	2.15
113	2XMM J100132.2+013419	1.355	3	-13.78	44.15	-0.79	2.19
114	2XMM J100136.4+025304	2.116	3	-13.54	44.84	1.79	2.37
115	2XMM J100145.2+022456	2.032	3	-14.00	44.33	0.90	2.09
116	2XMM J100156.3+555440	1.152	2	-13.33	44.44	2.63	2.63
117	2XMM J100201.5+020330	2.023	6	-14.20	44.12	-0.42	2.27
118	2XMM J100202.7+022434	0.9877	8	-13.57	44.05	0.56	2.66
119	2XMM J100205.2+554258	1.151	2	-13.59	44.18	2.63	2.63

**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
120	2XMM J100210.6+023026	1.161	6	-13.41	44.36	-0.74	2.63
121	2XMM J100219.5+015537	1.51	7	-13.60	44.44	-0.82	2.34
122	2XMM J100226.3+021923	1.292	5	-13.38	44.50	0.50	2.38
123	2XMM J100232.1+023537	0.6576	4	-13.06	44.14	-0.62	2.52
124	2XMM J100234.3+015011	1.504	4	-13.37	44.67	-0.81	2.16
125	2XMM J100236.6+015949	1.516	2	-14.07	43.97	1.84	1.84
126	2XMM J100238.2+013747	2.506	2	-13.63	44.91	2.02	2.02
127	2XMM J100243.5+324812	0.7116	2	-13.17	44.12	2.52	2.52
128	2XMM J100248.9+325130	1.537	2	-13.13	44.93	2.35	2.35
129	2XMMi J100251.6+022905	2.006	2	-13.81	44.51	2.26	2.26
130	2XMM J100254.4+324039	0.8288	2	-12.05	45.39	2.49	2.49
131	2XMM J100302.9+015208	1.8	4	-13.36	44.85	-0.86	2.12
132	2XMM J100309.2+022037	1.964	3	-13.91	44.39	0.39	2.12
133	2XMM J100309.4+554134	0.6736	2	-12.95	44.28	2.74	2.74
134	2XMM J100324.5+021830	0.5184	2	-12.79	44.17	2.40	2.40
135	2XMM J100926.6+533424	1.73	2	-13.02	45.16	2.94	2.94
136	2XMMi J102129.1+215609	1.465	2	-13.35	44.67	1.82	1.82
137	2XMMi J102134.2+215437	1.536	2	-13.49	44.57	1.81	1.81
138	2XMMi J102223.7+383424	1.357	2	-13.62	44.31	0.82	0.82
139	2XMMi J102224.0+215832	1.165	2	-13.64	44.14	1.88	1.88
140	2XMMi J102255.3+383007	0.658	2	-13.57	43.64	0.98	0.98
141	2XMM J102310.0+194248	1.594	2	-13.64	44.45	2.93	2.93
142	2XMM J102313.2+195651	1.086	2	-13.13	44.58	3.02	3.02
143	2XMM J102318.6+194835	1.761	2	-13.77	44.42	2.90	2.90
144	2XMM J102423.7+195250	1.635	2	-13.83	44.29	2.92	2.92
145	2XMM J103216.0+505119	0.1731	4	-12.44	43.46	0.71	3.03
146	2XMM J103227.9+573822	1.969	2	-13.23	45.07	1.15	1.15
147	2XMM J103518.5+392934	0.8774	2	-13.61	43.89	3.00	3.00
148	2XMM J104401.1+212804	1.494	3	-13.17	44.86	0.98	1.95
149	2XMM J104414.5+213203	1.17	3	-13.65	44.13	1.04	2.01
150	2XMM J104440.0+212643	1.504	3	-13.34	44.70	0.97	1.95
151	2XMM J104522.1+212614	0.8908	3	-13.07	44.44	1.10	2.07
152	2XMM J105039.5+572336	1.445	3	-13.35	44.64	-0.09	0.39
153	2XMM J105050.0+573819	1.285	3	-13.33	44.55	-0.06	0.42
154	2XMM J105201.3+441417	1.79	2	-13.72	44.48	1.02	1.02
155	2XMM J105204.5+440152	1.524	2	-13.47	44.58	1.06	1.06
156	2XMM J105221.0+440439	0.9677	2	-13.16	44.43	1.17	1.17
157	2XMM J105224.9+441505	0.4435	2	-12.48	44.33	1.31	1.31
158	2XMM J105239.6+572431	1.112	14	-12.90	44.83	-0.05	2.65
159	2XMM J105316.7+573550	1.205	13	-12.78	45.03	-0.09	2.64
160	2XMM J105404.1+574019	1.102	3	-13.45	44.27	-0.07	0.26
161	2XMM J105422.5+572031	2.972	3	-13.94	44.76	-0.35	-0.02
162	2XMMi J105540.0+065552	0.596	5	-13.46	43.64	0.08	2.01
163	2XMMi J105549.4+065542	0.9024	5	-12.77	44.75	0.01	1.93
164	2XMMi J105603.7+070235	2.303	5	-13.38	45.07	-0.23	1.70
165	2XMMi J105622.1+071250	1.656	5	-13.09	45.05	-0.14	1.79
166	2XMM J110253.4+360425	1.795	2	-13.90	44.31	2.59	2.59
167	2XMM J110309.2+380914	1.721	2	-13.44	44.73	1.02	1.02
168	2XMM J110320.1+380931	1.752	12	-13.76	44.43	-0.87	2.83
169	2XMM J110334.7+355108	1.199	2	-13.75	44.06	2.70	2.70
170	2XMM J110400.3+380231	1.621	21	-13.74	44.37	-1.31	3.05
171	2XMM J110449.0+381812	1.943	25	-13.54	44.75	-1.36	3.05
172	2XMM J110458.2+250422	3.574	2	-13.48	45.39	2.20	2.20
173	2XMM J110547.1+380948	1.153	6	-13.12	44.65	-1.22	2.93
174	2XMM J110550.6+251747	0.6247	2	-12.53	44.62	2.65	2.65
175	2XMM J110602.6+251227	1.683	2	-13.48	44.66	2.43	2.43
176	2XMMi J111233.4+060619	3.278	2	-14.09	44.70	-0.36	-0.36
177	2XMMi J111303.6+061620	0.8491	2	-13.16	44.30	0.00	0.00
178	2XMM J111506.0+424949	0.3005	2	-13.16	43.27	2.83	2.83
179	2XMM J111747.3+075400	1.961	3	-13.88	44.42	0.72	2.50

**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
180	2XMM J111816.9+074558	1.735	3	-12.42	45.76	0.76	2.54
181	2XMM J111840.5+075323	1.461	3	-13.37	44.63	0.80	2.58
182	2XMM J111842.3+212014	1.924	2	-13.61	44.67	2.58	2.58
183	2XMM J111853.4+074946	2.042	3	-13.66	44.68	0.71	2.49
184	2XMM J111902.0+213315	1.933	2	-13.39	44.90	2.58	2.58
185	2XMM J111928.3+130250	2.394	2	-12.81	45.68	2.03	2.03
186	2XMM J113205.1+530726	1.84	2	-13.74	44.50	1.82	1.82
187	2XMM J113224.0+525157	0.837	2	-13.38	44.07	2.00	2.00
188	2XMM J114405.6+195734	0.9541	2	-13.06	44.52	1.96	1.96
189	2XMM J115606.7+233106	1.593	3	-12.90	45.19	0.79	2.99
190	2XMM J115726.2+434954	1.597	2	-13.23	44.87	-0.16	-0.16
191	2XMM J115838.5+435505	1.208	2	-13.63	44.18	-0.09	-0.09
192	2XMM J115851.0+435048	0.2871	2	-12.92	43.46	0.14	0.14
193	2XMM J115906.3+434643	1.462	2	-13.50	44.51	-0.14	-0.14
194	2XMM J115911.3+440819	1.438	2	-13.50	44.50	-0.13	-0.13
195	2XMM J120405.8+201345	0.5985	3	-12.83	44.27	1.10	2.05
196	2XMM J120414.4+351759	2.359	2	-13.86	44.62	1.05	1.05
197	2XMM J120432.7+202434	2.09	3	-13.34	45.02	0.81	1.76
198	2XMM J120504.4+352209	2.278	2	-13.64	44.80	1.06	1.06
199	2XMM J120943.4+393644	2.333	2	-13.53	44.94	-0.79	-0.79
200	2XMM J121001.7+392151	2.955	3	-13.66	45.03	-0.86	2.70
201	2XMM J121111.1+393320	1.529	8	-13.68	44.37	-0.81	2.93
202	2XMM J121129.3+392513	1.671	8	-13.70	44.45	-0.84	2.91
203	2XMM J121426.5+140259	1.279	4	-12.83	45.05	-0.04	3.02
204	2XMM J121509.4+135450	0.8473	2	-12.76	44.70	2.78	2.78
205	2XMM J121753.1+294305	1.647	8	-13.28	44.85	-0.13	2.84
206	2XMM J121808.5+471613	0.398	7	-12.75	43.95	1.48	3.19
207	2XMM J121836.1+054628	0.7954	2	-13.08	44.32	3.09	3.09
208	2XMM J121849.5+295451	0.962	8	-13.21	44.38	0.00	2.97
209	2XMM J121911.1+470708	1.901	5	-13.60	44.66	1.71	2.87
210	2XMM J121938.6+064022	1.187	2	-13.23	44.57	1.88	1.88
211	2XMM J121952.2+472058	0.6531	6	-12.86	44.34	1.40	3.12
212	2XMMi J122051.4+282217	1.524	4	-13.58	44.47	-0.20	0.37
213	2XMM J122135.6+280614	3.288	5	-12.70	46.09	-0.43	2.71
214	2XMM J122222.7+041623	1.19	2	-13.54	44.27	2.53	2.53
215	2XMM J122442.2+332941	0.7763	3	-13.02	44.35	2.09	2.49
216	2XMM J122525.0+333651	0.7654	3	-13.21	44.14	2.09	2.49
217	2XMM J122532.4+332532	0.5859	3	-12.87	44.22	2.14	2.54
218	2XMM J122549.9+332455	1.133	2	-13.82	43.93	2.41	2.41
219	2XMM J122556.1+130656	1.35	2	-13.48	44.45	2.59	2.59
220	2XMM J122607.1+334559	1.158	3	-12.96	44.82	2.00	2.41
221	2XMM J122627.0+332148	0.875	3	-13.67	43.83	2.07	2.47
222	2XMM J122645.3+332801	3.339	2	-14.00	44.81	1.63	1.63
223	2XMM J122703.3+125402	1.273	2	-13.60	44.27	2.60	2.60
224	2XMM J122731.6+333259	1.608	2	-13.93	44.17	2.62	2.62
225	2XMM J122923.7+075359	0.8538	2	-12.95	44.52	2.49	2.49
226	2XMM J122931.2+015249	0.7704	19	-13.57	43.79	-0.81	3.24
227	2XMM J122934.7+015658	1.921	25	-13.29	44.99	-1.43	3.03
228	2XMM J122951.5+105827	1.847	2	-13.65	44.59	0.14	0.14
229	2XMM J123035.4+153510	0.8028	2	-12.84	44.57	0.30	0.30
230	2XMM J123049.7+640848	1.041	2	-13.57	44.10	2.72	2.72
231	2XMM J123054.1+110011	0.2359	3	-11.74	44.45	0.50	2.86
232	2XMM J123110.3+161258	1.453	2	-13.05	44.95	-1.02	-1.02
233	2XMM J123126.4+105111	0.3039	3	-12.76	43.68	0.48	2.83
234	2XMM J123147.1+123835	0.2916	2	-12.69	43.71	3.29	3.29
235	2XMM J123148.0+143741	1.706	2	-13.37	44.80	1.90	1.90
236	2XMM J123229.6+641115	0.7423	2	-12.98	44.34	2.79	2.79
237	2XMM J123622.9+621526	2.588	7	-13.96	44.61	-0.80	2.42
238	2XMM J123716.0+620323	2.068	5	-14.31	44.04	0.24	2.49
239	2XMM J123759.5+621102	0.9095	7	-13.05	44.48	-0.52	2.69

**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
240	2XMM J123800.9+621336	0.4402	7	-13.21	43.60	-0.40	2.81
241	2XMM J123816.0+620208	1.005	3	-14.01	43.62	-0.54	0.85
242	2XMM J124126.5+323924	1.787	2	-13.50	44.70	0.95	0.95
243	2XMM J124206.0+141920	1.951	2	-13.26	45.03	2.57	2.57
244	2XMM J124207.6+333117	0.5148	2	-13.38	43.58	0.07	0.07
245	2XMM J124300.3+113554	2.94	2	-13.12	45.57	2.81	2.81
246	2XMM J124406.9+113524	1.344	2	-13.07	44.85	3.04	3.04
247	2XMM J125317.6+310550	0.7824	2	-13.40	43.98	1.22	1.22
248	2XMM J125344.9+305820	2.067	2	-13.42	44.93	0.98	0.98
249	2XMM J125553.0+272405	0.3158	2	-12.22	44.25	2.92	2.92
250	2XMM J125627.9+215406	1.871	5	-13.29	44.96	0.77	2.41
251	2XMM J125629.6+271507	2.523	2	-13.56	44.98	2.49	2.49
252	2XMM J125702.9+273801	1.13	3	-13.35	44.40	0.67	1.93
253	2XMM J125708.4+271330	1.664	3	-13.27	44.86	0.15	2.91
254	2XMM J125712.0+274216	0.7925	2	-13.03	44.37	2.01	2.01
255	2XMM J125732.6+215708	1.934	4	-13.69	44.60	1.78	2.40
256	2XMMi J125732.9+473224	1.859	2	-13.57	44.67	-0.18	-0.18
257	2XMM J125745.1+273210	1.56	5	-13.77	44.30	0.17	2.93
258	2XMM J125803.0+345125	2.037	2	-14.01	44.33	0.93	0.93
259	2XMM J125818.5+275937	1.723	2	-13.91	44.26	1.82	1.82
260	2XMM J125831.7+275330	1.14	5	-13.04	44.72	-0.82	2.93
261	2XMM J125859.2+275308	1.135	12	-13.30	44.45	-0.82	2.94
262	2XMM J125903.9+344702	0.6075	3	-13.01	44.12	1.20	2.03
263	2XMM J125923.3+272720	1.99	2	-13.46	44.85	0.15	0.15
264	2XMM J125931.0+282706	1.094	7	-13.70	44.02	-0.06	3.02
265	2XMM J130002.7+345043	1.054	3	-13.25	44.43	1.10	1.92
266	2XMM J130028.5+283010	0.6467	7	-12.09	45.10	0.05	2.95
267	2XMM J130048.1+282321	1.923	7	-13.42	44.86	-0.20	2.70
268	2XMM J130100.8+281944	1.36	7	-13.09	44.85	-0.11	2.79
269	2XMM J130120.0+282137	1.369	8	-12.73	45.21	-0.11	2.79
270	2XMMi J131134.9+231818	1.527	2	-13.50	44.55	0.52	0.52
271	2XMMi J131213.6+231958	1.514	3	-13.10	44.94	-0.17	0.60
272	2XMMi J131236.2+231630	3.711	2	-13.86	45.04	0.24	0.24
273	2XMMi J131606.6+421513	1.841	2	-13.32	44.92	0.89	0.89
274	2XMMi J131712.9+420439	1.031	2	-12.78	44.88	1.03	1.03
275	2XMM J132307.7+655446	0.6485	2	-12.91	44.28	2.64	2.64
276	2XMM J132827.3+581839	3.139	4	-14.07	44.68	0.01	2.54
277	2XMM J132938.5+471854	1.027	4	-13.27	44.39	0.31	2.78
278	2XMM J133028.3+242253	1.919	2	-13.66	44.62	0.64	0.64
279	2XMM J133114.5+241650	2.265	2	-13.72	44.71	0.59	0.59
280	2XMM J133342.3+380336	1.077	3	-13.16	44.54	-0.09	0.75
281	2XMM J133417.5+375722	1.142	3	-13.25	44.51	-0.10	0.74
282	2XMM J133542.5+375542	1.899	3	-13.84	44.43	-0.23	0.61
283	2XMM J133807.5+242410	0.6313	4	-12.97	44.20	0.07	3.16
284	2XMM J133859.2+272702	1.792	2	-13.62	44.58	1.17	1.17
285	2XMM J133913.3+271818	0.6819	2	-12.71	44.53	1.39	1.39
286	2XMM J133944.4-001451	1.269	2	-13.82	44.05	1.92	1.92
287	2XMMi J134050.7+301610	1.519	2	-13.52	44.53	-0.10	-0.10
288	2XMMi J134132.8+301326	0.7355	2	-13.20	44.12	0.06	0.06
289	2XMM J134256.5+000057	0.8041	2	-12.76	44.65	2.48	2.48
290	2XMM J134323.6+001223	0.8731	3	-12.79	44.70	1.93	2.47
291	2XMM J134834.2+262205	0.9144	2	-12.67	44.86	2.69	2.69
292	2XMM J134848.2+262219	0.5949	2	-12.93	44.17	2.77	2.77
293	2XMM J134850.1+262503	2.915	2	-14.13	44.55	2.38	2.38
294	2XMM J135038.6+601901	1.165	2	-13.49	44.29	1.98	1.98
295	2XMM J135301.2+633256	3.16	2	-14.26	44.49	2.54	2.54
296	2XMM J135418.1+635705	1.618	3	-13.78	44.33	-0.11	2.74
297	2XMM J135810.6+653740	1.112	3	-13.07	44.66	1.25	1.58
298	2XMM J135842.7+652236	3.199	3	-13.81	44.95	0.95	1.28
299	2XMM J140001.6-014924	1.754	3	-13.40	44.79	1.83	2.67

**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
300	2XMM J140146.5+024433	4.442	4	-13.69	45.39	0.26	2.73
301	2XMMi J140148.2-014514	1.795	2	-13.78	44.44	1.82	1.82
302	2XMM J140349.4+432009	0.6664	2	-12.94	44.28	1.49	1.49
303	2XMM J140354.6+543246	3.258	2	-14.07	44.71	2.26	2.26
304	2XMM J140536.6+255140	0.9427	3	-13.01	44.55	0.04	2.96
305	2XMM J140541.0+432537	0.5199	2	-13.23	43.74	1.53	1.53
306	2XMMi J140547.2+260629	0.7244	2	-13.60	43.71	0.09	0.09
307	2XMM J140841.5+262943	1.885	2	-13.48	44.78	2.06	2.06
308	2XMM J140949.0+261347	2.945	2	-13.94	44.75	1.93	1.93
309	2XMM J141513.5+112216	1.554	2	-13.71	44.36	2.16	2.16
310	2XMM J141515.8+112344	1.229	2	-13.48	44.36	2.22	2.22
311	2XMM J141540.0+112407	1.074	2	-13.02	44.68	2.25	2.25
312	2XMM J141546.2+112943	2.56	2	-13.74	44.82	2.02	2.02
313	2XMM J141551.6+522743	2.587	2	-14.08	44.49	-0.30	-0.30
314	2XMM J141642.3+521813	1.285	3	-13.68	44.20	-0.98	-0.11
315	2XMM J141647.3+521115	2.152	3	-13.56	44.83	-1.12	-0.25
316	2XMM J141652.0+113201	0.6881	2	-13.00	44.25	2.34	2.34
317	2XMM J141745.6+250242	1.36	3	-13.61	44.32	-0.00	1.93
318	2XMM J141838.2+522400	1.118	3	-13.23	44.51	-0.94	-0.07
319	2XMMi J142258.2+193322	1.603	3	-12.65	45.45	-0.12	0.19
320	2XMMi J142259.6+194458	1.129	3	-13.71	44.04	-0.03	0.27
321	2XMM J142325.4+384032	0.2489	2	-12.47	43.78	2.73	2.73
322	2XMM J142335.9+383407	1.487	2	-13.60	44.42	2.43	2.43
323	2XMM J142355.5+383150	1.207	2	-13.08	44.74	2.49	2.49
324	2XMM J142406.6+383714	1.562	2	-13.11	44.96	2.42	2.42
325	2XMM J142435.9+421030	2.218	2	-13.11	45.30	1.65	1.65
326	2XMM J142455.5+421408	0.3162	2	-12.03	44.45	2.04	2.04
327	2XMM J142519.0+422158	1.104	2	-13.45	44.28	1.83	1.83
328	2XMM J142737.7+424450	1.953	7	-13.55	44.74	-0.17	2.71
329	2XMM J143025.8+415957	0.3524	3	-12.87	43.71	1.46	2.83
330	2XMM J143440.4+484139	1.945	2	-13.50	44.79	1.01	1.01
331	2XMM J143513.9+484149	1.887	2	-13.48	44.78	1.02	1.02
332	2XMM J143621.2+484606	2.395	2	-13.61	44.88	0.95	0.95
333	2XMMi J143914.1+002320	0.8826	2	-13.05	44.45	1.99	1.99
334	2XMMi J143931.9+000453	1.405	2	-13.33	44.63	1.89	1.89
335	2XMMi J144008.6+001630	1.502	2	-13.08	44.95	1.87	1.87
336	2XMMi J144259.9-003725	1.817	2	-12.93	45.29	-0.43	-0.43
337	2XMMi J144305.1-004825	0.7007	2	-13.68	43.59	-0.22	-0.22
338	2XMMi J144308.1-004913	1.372	2	-12.97	44.97	-0.36	-0.36
339	2XMM J144729.9+030520	1.782	2	-13.47	44.73	2.10	2.10
340	2XMM J150424.9+102938	1.839	4	-12.31	45.92	-1.17	2.76
341	2XMM J150428.3+101856	1.011	4	-12.95	44.69	-1.02	2.91
342	2XMM J150545.6+014145	1.424	2	-13.22	44.76	1.94	1.94
343	2XMM J150916.2+332730	1.656	2	-13.46	44.67	2.52	2.52
344	2XMM J150948.6+333626	0.5124	2	-13.17	43.78	2.77	2.77
345	2XMM J151126.4+565934	1.031	2	-13.45	44.21	2.12	2.12
346	2XMM J151453.9+561032	1.287	2	-13.21	44.67	0.54	0.54
347	2XMM J151510.1+562834	0.7207	2	-13.22	44.07	0.67	0.67
348	2XMM J151651.2+562850	1.309	2	-13.35	44.55	0.54	0.54
349	2XMM J152322.3+274931	0.424	2	-13.90	42.87	2.80	2.80
350	2XMM J152553.8+513649	2.883	3	-12.83	45.84	0.03	1.54
351	2XMM J153322.8+324351	1.899	3	-13.53	44.74	1.72	2.48
352	2XMMi J153434.8+574723	1.236	4	-13.53	44.31	-0.06	0.42
353	2XMMi J153458.3+575625	1.129	4	-13.23	44.52	-0.03	0.45
354	2XMM J153617.2+544709	1.45	4	-13.15	44.85	-0.08	2.68
355	2XMM J153634.9+544317	0.9136	4	-13.23	44.30	0.02	2.79
356	2XMM J153641.5+543505	0.447	4	-13.54	43.28	0.14	2.91
357	2XMMi J153716.2+574838	0.6406	4	-12.95	44.23	0.08	0.56
358	2XMM J154234.3+540137	0.3959	2	-13.77	42.93	0.44	0.44
359	2XMM J154316.4+540526	0.2452	2	-12.85	43.38	0.49	0.49



**Table 1.** continued.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{epo}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	$\log \tau_{min}$ (7)	$\log \tau_{max}$ (8)
360	2XMM J154359.4+535902	2.371	2	-13.05	45.43	0.06	0.06
361	2XMM J154530.3+484608	0.3993	4	-12.16	44.55	0.15	3.06
362	2XMM J154535.8+484713	1.404	3	-13.34	44.63	0.40	2.82
363	2XMM J160318.0+430116	1.156	2	-13.42	44.36	-0.04	-0.04
364	2XMM J160419.0+325631	2.281	2	-13.46	44.98	2.06	2.06
365	2XMM J160501.3+174515	2.996	2	-13.75	44.95	-0.36	-0.36
366	2XMM J160513.1+325829	2.256	5	-13.57	44.87	0.09	2.10
367	2XMM J160603.6+174307	1.105	2	-13.58	44.15	-0.08	-0.08
368	2XMM J160613.5+325554	1.874	6	-13.57	44.68	-0.17	2.72
369	2XMM J161706.8+122606	1.637	2	-13.36	44.76	-1.12	-1.12
370	2XMMi J162710.3+350118	2.288	2	-13.39	45.05	-0.21	-0.21
371	2XMMi J162722.4+351039	1.677	2	-13.31	44.83	-0.12	-0.12
372	2XMM J162855.6+394034	1.521	3	-13.30	44.75	-0.11	1.22
373	2XMM J162937.1+394059	0.7241	3	-13.08	44.23	0.05	1.38
374	2XMM J162940.4+393124	2.146	3	-13.50	44.89	-0.21	1.12
375	2XMMi J163023.5+242546	2.312	3	-13.85	44.61	-0.22	0.38
376	2XMM J164056.2+363404	0.6761	2	-12.42	44.81	0.08	0.08
377	2XMM J165430.7+395418	0.3397	2	-12.39	44.16	0.17	0.17
378	2XMM J165713.2+352441	2.331	6	-13.86	44.61	-0.22	2.52
379	2XMM J170554.0+240638	0.9021	2	-13.27	44.25	2.29	2.29
380	2XMM J170606.2+240305	0.7912	3	-13.40	43.99	1.94	2.31
381	2XMM J170639.3+240606	0.8358	2	-13.44	44.01	1.93	1.93
382	2XMMi J171029.2+590833	0.8637	2	-12.87	44.61	0.87	0.87
383	2XMMi J171126.8+585543	0.5373	2	-12.77	44.23	0.96	0.96
384	2XMMi J171144.9+584917	1.533	2	-13.16	44.89	0.74	0.74
385	2XMM J171359.4+640939	1.36	2	-13.52	44.42	1.29	1.29
386	2XMMi J171815.9+584613	1.413	6	-13.38	44.59	-0.08	1.92
387	2XMMi J171818.1+584904	0.6344	7	-13.10	44.07	0.09	2.09
388	2XMMi J171930.2+584804	2.081	8	-13.05	45.30	-0.19	1.82
389	2XMMi J172026.4+263816	1.145	3	-13.56	44.20	-0.04	0.27
390	2XMMi J172052.1+590154	0.3512	8	-12.77	43.81	0.17	2.17
391	2XMMi J172130.9+584405	0.9997	7	-12.72	44.91	0.00	2.00
392	2XMM J172255.3+320307	0.2752	3	-12.90	43.44	0.79	1.24
393	2XMM J172256.7+321427	1.173	3	-12.83	44.95	0.56	1.00
394	2XMMi J172310.4+595105	0.9899	2	-13.33	44.29	0.47	0.47
395	2XMMi J172353.2+600002	1.453	2	-13.09	44.91	0.38	0.38
396	2XMM J212912.1+120750	1.149	4	-13.50	44.27	1.90	2.64
397	2XMM J215703.7-073829	1.899	2	-13.39	44.87	2.28	2.28
398	2XMM J221640.1+001619	1.019	2	-13.47	44.18	1.14	1.14
399	2XMM J221708.9+002718	1.112	2	-13.20	44.53	1.13	1.13
400	2XMM J221715.1+002615	0.7532	2	-13.10	44.24	1.21	1.21
401	2XMM J221738.4+001207	1.121	2	-13.76	43.99	1.12	1.12
402	2XMM J221739.2+002903	1.646	2	-14.21	43.91	1.03	1.03
403	2XMM J221751.3+001146	1.491	2	-13.64	44.39	1.05	1.05
404	2XMM J221755.2+001513	2.092	2	-13.90	44.46	0.96	0.96
405	2XMM J221806.6+000534	2.276	2	-13.95	44.49	0.93	0.93
406	2XMM J231733.6+001129	0.8407	2	-13.29	44.16	1.98	1.98
407	2XMM J231742.5+000535	0.3209	2	-12.26	44.23	2.13	2.13
408	2XMM J231850.6+002554	1.592	2	-13.38	44.71	2.81	2.81
409	2XMMi J232810.5+150012	1.536	2	-13.64	44.42	2.33	2.33
410	2XMMi J235800.6-000107	1.454	2	-13.18	44.83	1.91	1.91
411	2XMMi J235844.9-000723	1.979	2	-13.52	44.79	1.82	1.82
412	2XMMi J235845.6-000458	1.609	2	-13.24	44.86	1.88	1.88

**Table 2.** Swift sample.

$N_{sou}$ (1)	name (2)	$z$ (3)	$N_{bin}$ (4)	$\log f_X$ (5)	$\log L_X$ (6)	GRB field (7)
1	SWIFTFT J005503+1408.0	1.67	14	-13.17	45.39	GRB050904
2	SWIFTFT J020643+0023.7	1.22	15	-13.60	44.85	GRB060908
3	SWIFTFT J020710+0010.3	0.92	16	-13.62	44.37	GRB060908
4	SWIFTFT J020727+0028.9	1.18	12	-13.53	44.65	GRB060908
5	SWIFTFT J075122+3109.8	1.31	24	-13.44	44.77	GRB070125
6	SWIFTFT J082057+3153.9	1.07	13	-12.72	45.26	GRB051227
7	SWIFTFT J084819+1336.1	1.48	22	-13.02	45.35	GRB051016B
8	SWIFTFT J092733+3022.7	1.34	8	-13.42	45.04	GRB050505
9	SWIFTFT J092736+3020.0	1.26	12	-12.94	45.28	GRB050505
10	SWIFTFT J094821+3153.9	1.59	10	-13.43	45.07	GRB060108
11	SWIFTFT J101609+4336.2	0.59	21	-12.80	44.59	GRB050319
12	SWIFTFT J101727+4329.0	1.17	17	-13.10	45.00	GRB050319
13	SWIFTFT J113805+4047.5	2.18	8	-13.13	45.62	GRB050215B
14	SWIFTFT J114502+5957.3	1.64	75	-13.39	45.06	GRB060319
15	SWIFTFT J120215+1045.3	1.32	29	-13.11	45.07	GRB050408
16	SWIFTFT J121017+3956.7	0.40	15	-12.74	44.20	GRB070419A
17	SWIFTFT J121645+3529.6	2.01	21	-13.39	45.33	GRB060712
18	SWIFTFT J124958+3028.8	1.63	5	-13.13	45.28	GRB050520
19	SWIFTFT J131524+1638.0	1.44	19	-13.64	44.66	GRB070406
20	SWIFTFT J133128+4209.7	0.94	11	-13.67	44.11	GRB051008
21	SWIFTFT J140704+2735.8	2.22	17	-13.22	45.55	GRB060204B
22	SWIFTFT J141221+1657.9	1.87	7	-13.26	45.32	GRB060801
23	SWIFTFT J143646+2745.0	0.22	19	-13.50	42.43	GRB050802
24	SWIFTFT J144339+1229.4	1.98	5	-13.27	45.31	GRB060805
25	SWIFTFT J144419+1236.3	1.51	6	-13.49	44.95	GRB060805
26	SWIFTFT J160757+3221.8	1.42	12	-13.52	44.81	GRB060219
27	SWIFTFT J165004+3133.9	1.70	11	-13.50	44.98	GRB060807